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Canada - Saskatchewan Renewables — Conservation Demonstration Program

Final Report

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CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;
- To create employment in new or existing industries;
- To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

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SASK. 20

Rendering Vapour Waste Heat Recovery Project

Final Technical Report
on a Renewables-Conservation Demonstration Program Project

Conducted By
Canada Packers Inc.

And Partially Funded By

Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada

Project Leaders: A.J. Scriven and T.J. Molczan

Miscellaneous
Report FP-44

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SUMMARY

In December of 1982, Canada Packers Inc., started up a rendering vapour heat recovery system at its Moose Jaw Packinghouse plant. The system recovers previously lost waste heat from the vapour produced by four batch inedible rendering cookers. The vapour, which has the properties of saturated atmospheric steam, is cooled and condensed by incoming city water in a spiral type heat exchanger. The city water is preheated to about 65°C before it enters the plant's existing hot water heating system. Its temperature is then adjusted to the desired temperature by steam heating. The hot water is used for processing and sanitation.

The system has performed well during its first eight months of operation. There have been no unscheduled shutdowns. The rate of heat recovery averaged 3.90 GJ/h on the day shift and 1.19 GJ/h on the clean-up shift. The system is recovering about 77 percent of the available waste heat. Based on these results, the annual fuel savings have been estimated to be in excess of 477,000 m^3 of natural gas.

The $140,745 capital cost of the project was partially offset by $26,190 grant form the Canada/Saskatchewan Conservation and Renewable Energy Demonstration Agreement (CREDA). The first year savings have been estimated to be abut $53,000. Thus the simple payback will be 2.66 years without the grant and 2.16 years with the grant.

The feasibility of heat recovery from batch rendering systems depends on a sufficient demand for the recoverable heat to justify the necessary capital investment. Meat processing plants, like Moose Jaw Packinghouse, which combine slaughtering and inedible rendering can make the fullest use of the recovered heat because of the large volume of heated water required by the slaughtering and clean-up operations.

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1.0 BACKGROUND

1.1 Inedible Rendering

Inedible rendering converts the inedible by-products of slaughtering operations into industrial fats and animal feeds. The rendering process is usually made up of four steps :

- Size reduction;
- Evaporation of moisture by heating;
- Separation of fat from solids;
- Clarification and stabilization of fat.

Several different rendering systems are available to carry out these steps. They fall into two general categories; batch systems and continuous systems. Batch systems are most economic at production rates below 5,000 kg/h.

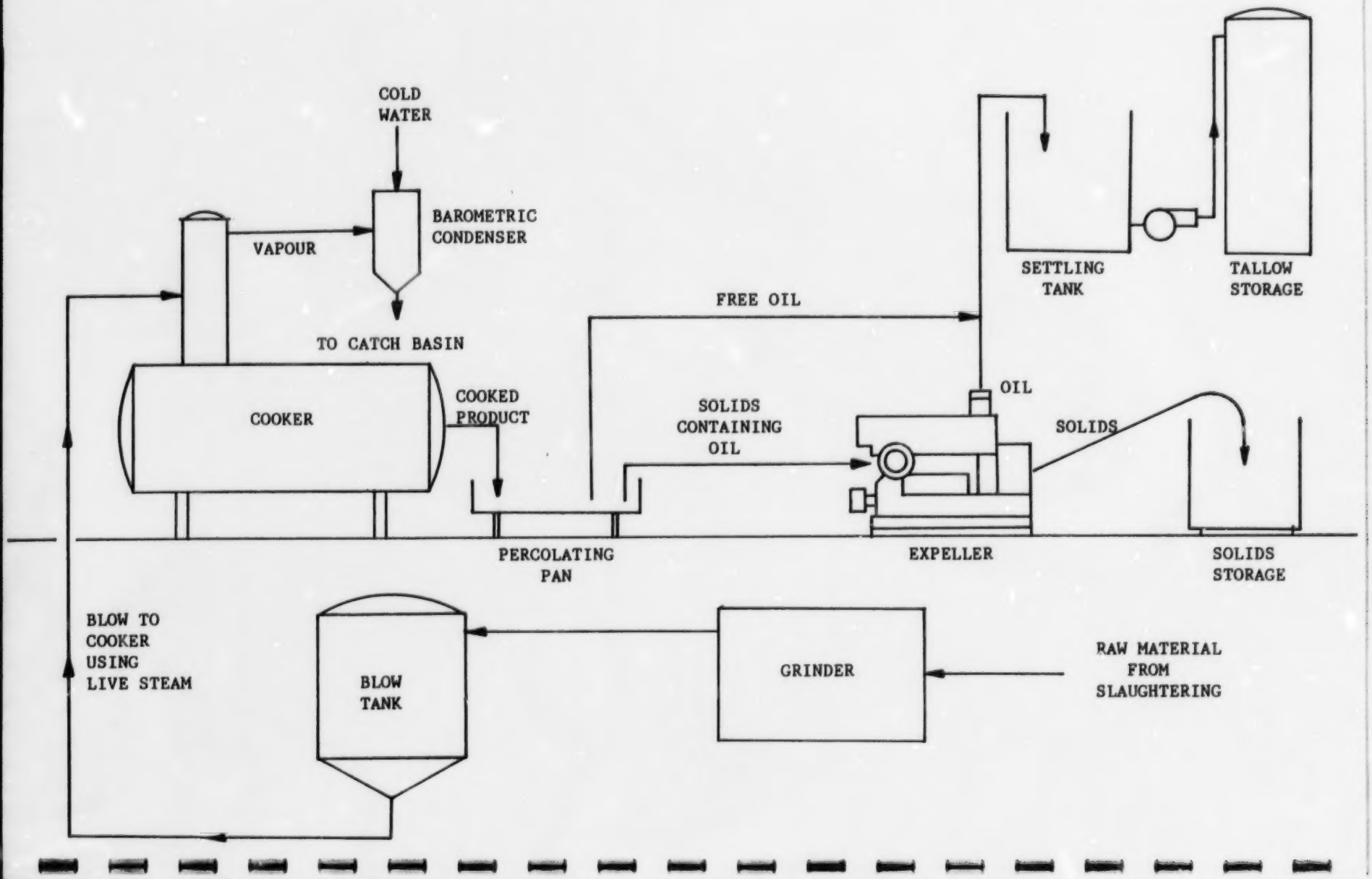
1.2 Batch Rendering System at Moose Jaw

The Moose Jaw Packinghouse plant uses a batch process for inedible rendering. The process is shown schematically in Figure 1.

Raw material to be rendered is transferred from the slaughtering operation by screw conveyors and chutes to the basement where it is reduced in size to small chunks in a grinder. The ground material is then stored in one of two blow tanks, also located in the basement. When a blow tank has been filled, it is pressurized with steam and the contents are blown into one of four steam jacketed, batch cookers, located on the main floor level.

The cookers evaporate the moisture from the raw material and melt the fat, causing it to separate from the solids as oil. Each cooker is sized to process up to 3,600 kg of raw materials in 3 to 4 hours.

FIGURE 1: SCHEMATIC OF BATCH RENDERING SYSTEM AT MOOSE JAW



At the end of a cook, when most of the moisture has been removed, the cooked product is emptied into a percolator box where free oil drains from the solids. The remaining oil is separated from the solids in an expeller (pressing machine). The oil (tallow) is clarified overnight in a settling tank and then pumped into a heated storage tank. The solids are conveyed to a storage bin.

1.3 Heat Recovery Opportunity

The cooking operation produces a large amount of waste heat. A typical cooker load of 3,600 kg contains 60 percent moisture by weight, or 2,160 kg, which is evaporated and leaves the cooker as 100°C, saturated vapour. Prior to installation of the present heat recovery system the vapour was piped to barometric condensers where it was condensed by direct contact with re-cycled effluent pumped from the sewage catch basin. The solution of condensate and effluent was discharged at a temperature of 60°C and returned to the sewage catch basin.

1.3.1 First Attempt To Recover Waste Heat

The benefits of recovering the waste heat from the rendering system were recognized when the Moose Jaw plant was being designed. When the plant opened in 1975 it included a shell and tube heat exchanger designed to pre-heat city water using the hot discharge water leaving the barometric condensers. This system was not successful due to severe fouling caused by the solids and grease in the effluent used by the condensers. The system was abandoned in 1978 because it proved too costly to maintain.

1.3.2 Basis For New Heat Recovery System

Due to the continued escalation of fuel prices Canada Packers decided to look for another method to recover waste heat from rendering. A method was proposed in which the vapour would bypass the barometric condensers and be condensed, much like boiler steam, in a steam to water heat exchanger. This would eliminate the fouling caused by the effluent used in the condensers (see previous section).

A study was carried out in 1980 to determine the feasibility of rendering heat recovery and to obtain the necessary data on which to base a system design. Its major findings were:

- nearly 80 percent of the annual fuel consumption was used for steam production. The remainder was used in gas fired heaters for space heating.
- the daily steam consumption was divided almost equally between inedible rendering and the heating of water for processing and sanitation.
- over 95 percent of the heat used for rendering was transferred to the rendering vapour.

These results indicated that a reasonably good match existed between rendering vapour production and hot water heating. During the slaughtering operations on the day shift, hot water demand was sufficient to use all of the available waste heat. On the afternoon shift, which is the clean-up shift, there was a reduced demand for hot water, which would result in an excess of waste heat.

Preliminary estimates of capital costs and potential energy cost savings indicated that a rendering vapour heat recovery project could meet the company's payback guidelines. Thus a detailed engineering design was prepared by the Company's Corporate Engineering department. In addition, a application for funding assistance through the Canada/Saskatchewan CREDA program was submitted to help offset some of the technical risks of the project by improving its economic return. This would be the first demonstration of this type of rendering vapour heat recovery technology in Canada.

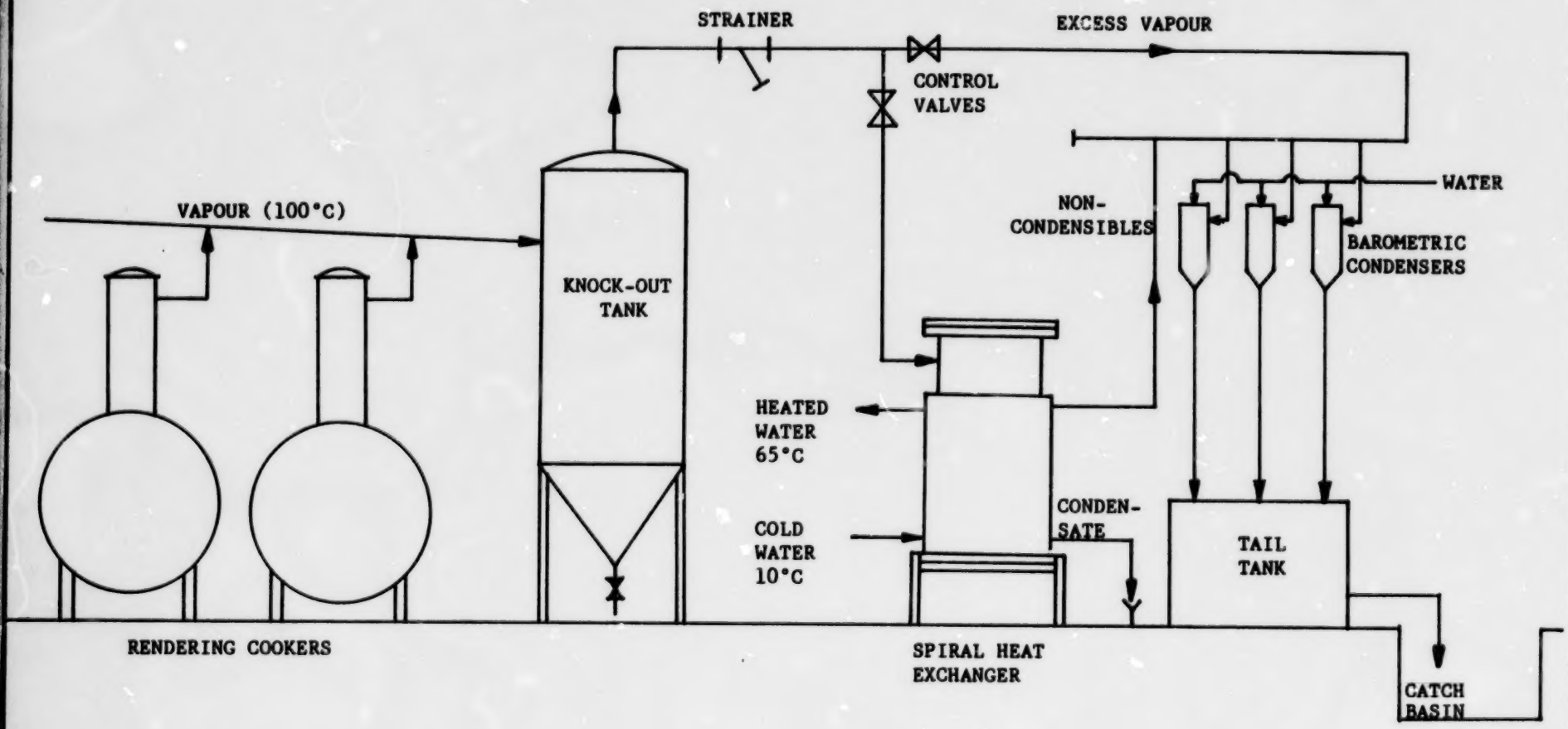
2.0 RENDERING VAPOUR HEAT RECOVERY SYSTEM

The heat recovery system was designed to recover up to 10 GJ/h of waste heat from the rendering cookers. The heat would be used to preheat up to 40 m^3/h of water by 50°C. The system was installed during the fall of 1982 and became operational in December, 1982.

2.1 System Description

The heat recovery system recovers waste heat from the rendering vapour by means of a condensing heat exchanger which preheats cold water before it enters the plant's water heating system. A schematic sketch of the heat recovery system is shown in Figure 2.

FIGURE 2: SCHEMATIC OF RENDERING VAPOUR HEAT RECOVERY SYSTEM



2.2 Major Components

2.2.1 Knock-Out Tank

Vapour from each cooker passes through a header to a vertical tank called the knock-out tank. The tank is designed to protect the heat exchanger from slugs of unrendered material which may be blown accidently through a cooker and into the header during the charging operation. It has been sized to contain the contents of one full cooker charge, and has a conical bottom with a large valve to permit easy draining.

The vapour header and knock-out tank are insulated to reduce heat losses.

2.2.2 Strainer

A large strainer in the vapour line between the knock-out tank and the heat exchanger filters out any fine particles that may remain in the vapour stream. The strainer is cleaned once each week to prevent any loss of pressure.

2.2.3 Heat Exchanger

A stainless steel, spiral type heat exchanger was selected for this application. It is essentially a welded assembly of two long metal strips that are wrapped to form a pair of concentric spiral passages. The ends of the passages are sealed so that the heat transfer occurs through two long, continuous, leakproof chambers. Rendering vapour flows through one chamber in counter-current flow to the cold water in the other chamber. This configuration causes the vapour to condense and under certain conditions allows sub-cooling of the condensate to about 50°C. Sub-cooling maximizes heat recovery. The degree of sub-cooling will depend on the relative flow rates of vapour and water.

The heat exchanger is mounted vertically on pipe legs. Both the top and bottom are fitted with removable covers to permit relatively easy cleaning of both channels.

2.2.4 Barometric Condensers

Three of the barometric condensers which had been used to condense the rendering vapour prior to installation of the heat recovery system have been retained and are now used to condense any excess vapour. They are connected to the vapour header between the strainer and the heat exchanger. A water temperature controller adjusts the flow of vapour. When the temperature of the heated water rises above a pre-set limit (currently about 77°C), the vapour is diverted from the heat exchanger to the barometric condensers automatically by two butterfly valves.

3.0 Operating Performance

3.1 Operating Characteristics

The quantity of heat recovered is measured by an energy flow meter which records the heat transferred to the plant water by multiplying the temperature rise by the flow rate. The meter provides integrator readings of the total heat recovered and the total water heated. This data was read at the beginning of each by the stationary engineers. It has been used to derive basic information on the system's operating characteristics as well as to calculate the energy saved, as shown in Table 1. The table shows the quantity of water heated, its mean temperature rise, total heat recovered, and the mean heat recovery rate on both shifts.

TABLE 1: OPERATING PERFORMANCE DURING PRODUCTION AND CLEAN-UP SHIFTS

	PRODUCTION SHIFT				CLEAN-UP SHIFT				DAILY TOTAL
	Water Heated	Mean Temp Rise	Heat Recovered		Water Heated	Mean Temp Rise	Heat Recovered		Heat Recovered
Date	m^3	°C	Total GJ	Mean GJ/h	m^3	°C	Total GJ	Mean GJ/h	GJ
July 4	201	47.3	39.9	3.99	42.7	41.2	7.4	0.92	47.3
5	238	47.6	47.4	4.74	38.6	48.5	7.9	0.98	55.3
6	208	50.8	44.1	4.41	57.7	51.1	12.4	1.55	56.5
7	216	45.4	41.1	4.11	40.0	64.9	10.9	1.36	52.0
8	200	47.3	39.5	3.95	52.3	33.5	7.3	0.92	46.8
11	203	43.1	36.6	3.66	60.5	51.5	13.0	1.63	49.6
12	215	43.9	39.5	3.95	37.3	59.0	9.2	1.15	48.7
13	203	47.9	40.7	4.07	44.1	47.5	8.8	1.10	49.5
14	217	43.1	39.2	3.92	42.3	49.8	8.8	1.10	48.0
15	213	49.7	44.3	4.43	39.5	44.0	7.3	0.91	51.6
18	211	45.6	40.2	4.02	55.0	43.4	10.0	1.25	50.2
19	182	43.7	33.3	3.33	53.6	40.7	9.1	1.14	42.4
20	189	47.0	37.2	3.72	105.5	45.2	20.0	2.50	57.2
21	195	49.0	39.9	3.99	60.9	41.4	10.6	1.32	50.5
25	196	46.8	38.5	3.85	24.1	47.0	4.7	0.59	43.2
27	207	45.7	39.7	3.97	40.0	55.4	9.3	1.16	49.0
28	191	32.9	26.3	2.63	24.5	73.2	7.5	0.94	33.8
Aug. 2	193	49.1	39.7	3.97	38.2	68.7	11.0	1.37	50.7
3	195	43.0	35.0	3.50	36.4	70.3	10.7	1.34	45.7
4	189	48.1	38.0	3.80	35.5	64.1	9.5	1.19	47.5
Mean	203	45.9	39.0	3.90	46.4	50.3	9.8	1.22	48.8

The production shift consumed 203 m^3 of water which was heated an average of 45.9°C by the heat recovery system. Given the typical July city water temperature of 18°C, the water would have been heated to approximately 64°C. This is sufficiently hot for most applications, however a portion of the water had to be heated to 82°C using the existing steam heaters, for use in sanitation equipment.

The clean-up shift used an average of 46.4 m^3 of water which was heated by 50.3°C. The quantity of heat and the temperature of the water was sufficient for all of the clean-up operations. Therefore it has become a standard procedure to shut down the steam water heaters promptly at the beginning of the shift to reduce stand-by losses.

3.2 Heat Recovery Rate

Table 1 shows that the average heat recovery rate was 3.90 GJ/h on the production shift and 1.19 GJ/h on the clean-up shift. The lower rate of heat recovery during clean-up had been expected due to an insufficient hot water demand to use all of the available waste heat.

Table 2 shows that 5982 GJ of heat was recovered during the monitoring period, at an average daily rate of 54.4 GJ. Based on production throughput, the theoretical amount of heat which could have been recovered was 7800 GJ.

3.3 Utilization

The heat recovery system has operated without any unscheduled downtime since it went into operation. There are two main reasons for this excellent result. First, the heat exchanger's heat transfer surfaces have been relatively free from fouling. An inspection after five months of operation revealed that the vapour side of the heat exchanger needed only to be cleaned with a hot water hose. This indicated that the vapour was being adequately cleaned of contaminants by the knock-out tank and strainer. The second reason for the system's high rate of utilization is that it has been made an integral part of the water heating system and is completely automatic.

TABLE 2 : HEAT RECOVERED DURING MONITORING PERIOD

PERIOD	PRODUCTION DAYS	TOTAL HEAT RECOVERED GJ	DAILY HEAT RECOVERY RATE GJ/d
Mar. 07-13	5	254	50.8
14-20	4	249	62.3
21-27	5	306	61.2
28-07	8	486	60.8
Apr. 08-01	16	919	57.4
May 02-08	5	298	59.6
09-22	10	584	58.4
23-29	4	222	55.5
30-05	5	275	55.0
June 06-12	5	264	52.8
13-16	4	225	56.3
17-26	6	324	54.0
27-03	4	209	52.3
July 04-10	5	254	50.8
11-17	5	247	49.4
18-24	5	185	37.0
25-31	5	229	45.8
Aug. 01-07	4	205	51.3
08-14	5	247	49.4
	110	5,982	54.4

Thus, 76.7 percent of the theoretically available heat has been recovered. A higher percentage could have been recovered if the excess waste heat available on the clean-up shift could be used.

Fuel savings during the monitoring period have been estimated to be 210,000 m^3 of natural gas, as shown in Table 3. This estimate was obtained by multiplying the measured heat recovery data from Table 2 by an estimated fuel savings factor, which has been derived in Appendix 1. This factor takes into account the boiler steam saved by heating water with the waste heat and the combustion efficiency of the boiler.

The annual fuel savings can be estimated by projecting the savings during the monitoring period for a whole year. There were 110 production days during the monitoring period and there are 250 production days in a year, therefore the annual fuel savings can be calculated as follows :

$$= 250 \text{ d} \times 210{,}000 \text{ m}^3/110 \text{ d}$$

$$= 477{,}000 \text{ m}^3$$

Thus, the annual fuel savings are expected to be about 477,000 m^3 of natural gas.

TABLE 3 : REDUCTION IN FUEL USE

PERIOD	TOTAL HEAT RECOVERED GJ	FUEL SAVINGS m^3 (1)
Mar. 07-13	254	8,920
14-20	249	8,740
21-27	306	10,700
28-07	486	17,100
Apr. 08-01	919	32,300
May 02-08	298	10,500
09-22	584	20,500
23-29	222	7,790
30-05	275	9,650
June 06-12	264	9,270
13-16	225	7,900
17-26	324	11,400
27-03	209	7,340
July 04-10	254	8,920
11-17	247	8,670
18-24	185	6,490
25-31	229	8,040
Aug. 01-07	205	7,200
08-14	247	8,670
	5,982	210,000

(1) Fuel savings have been estimated by multiplying the gross heat recovered by a fuel savings factor of 35.1 m^3/GJ. (Appendix 1)

4.0 ECONOMIC ANALYSIS

4.1 Capital Cost

The major costs of the project are listed below:

ITEM	COST
Heat Exchanger (Installed)	$ 37,837
Vapour Piping	35,053
Water Piping	29,268
Knock-Out Tank	7,479
Relocate Barometric Spray Condensers	10,100
Insulation	7,500
Engineering	13,508
Total Installed Cost	$140,745

4.2 Operating Savings

4.2.1 Fuel Savings

Table 4 shows that during the monitoring period, 210,000 m^3 of natural gas were saved, a cost reduction of $23,500. Based on the estimated annual fuel savings of 477,000 m^3 (Section 3.2), the remaining first year fuel savings will be :

Annual Savings	477,000 m^3
Less Monitoring Period Savings	210,000 m^3
Remaining Savings	267,000 m^3

Given the current fuel price of 0.1234 $\$/m^3$, the additional cost reduction will be :

$$267{,}000\ m^3 \times 0.1234\ \$/m^3 = \$32{,}900$$

TABLE 4 : FUEL SAVINGS

PERIOD	FUEL SAVINGS m^3	FUEL PRICE $\$/m^3$	COST SAVINGS $
Mar. 07-13	8,920	0.1092	970
14-20	8,740	0.1092	950
21-27	10,700	0.1092	1,170
28-07	17,100	0.1092	1,870
Apr. 08-01	32,300	0.1092	3,530
May 02-08	10,500	0.1092	1,150
09-22	20,500	0.1092	2,240
23-29	7,790	0.1092	850
30-05	9,650	0.1092	1,050
June 06-12	9,270	0.1092	1,010
13-16	7,900	0.1092	860
17-26	11,400	0.1092	1,240
27-03	7,340	0.1092	800
July 04-10	8,920	0.1092	970
11-17	8,670	0.1234	1,070
18-24	6,490	0.1234	800
25-31	8,040	0.1234	990
Aug. 01-07	7,200	0.1234	890
08-14	8,670	0.1234	1,070
	210,000		$ 23,500

Therefore, the total first year savings will be :

Monitoring Period	$ 23,500
Remaining	32,900
Total	$ 56,400

4.2.2 Maintenance Costs

The following annual maintenance costs have been projected:

ITEM	COST
1. Inspect and clean heat exchanger.	$ 400
2. Clean strainer.	900
3. Clean out knock-out tank.	2,100
TOTAL	$3,400

4.2.3 Net Annual Savings

The net annual savings have been calculated as follows:

Fuel Savings	$56,400
less Maintenance Costs	3,400
Net Annual Savings	$53,000

4.3 Canada - Saskatchewan Renewables - Conservation Demonstration Agreement

The capital cost of the heat recovery system was reduced by a $26,190 contribution from the CREDA program. A further $10,100 has been allocated by CREDA to cover the cost of communicating the existence of the project to industry.

4.4 Simple Payback

Based on the capital cost of $140,745 and net annual savings of $53,000, the simple payback of the heat recovery system is:

$$\frac{\$140,745}{53,000} = 2.66 \text{ years.}$$

With the CREDA grant, the simple payback was improved to :

$$\frac{\$114,555}{53,000} = 2.16 \text{ years.}$$

5.0 CONCLUSIONS

The inedible rendering vapour heat recovery system installed at the Moose Jaw Packinghouse Plant has operated without any problems since it was installed in December, 1982. Canada Packers is confident that the project will achieve the projected return on investment.

The heat recovery system can be applied on any batch rendering system, provided that there is sufficient demand for the heat.

APPENDIX 1

Fuel Savings Factor

The fuel savings have been estimated by applying a fuel savings factor to the measured amount of heat recovered. The factor is calculated from two known quantities:

1. The recovered waste heat replaces heat derived from condensing saturated boiler steam, having a pressure of 0.79 MPa, absolute, and a latent heat of vapourization of 2.05 MJ/kg.

2. The boiler's measured fuel to steam ratio is 0.072 m^3/kg (cubic metres of natural gas per kilogram of steam raised).

Therefore the fuel saving factor can be calculated as follows:

$$\text{FUEL SAVINGS FACTOR} = \frac{0.072\ m^3/kg}{2.05\ MJ/kg}$$

$$= 0.0351\ m^3/MJ$$

$$= 35.1\ m^3/GJ$$

Thus 35.1 m^3 of natural gas are saved for every gigajoule of waste heat that is recovered.